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(54) **SLIDING BEARING**

(57) A sliding bearing (1) is provided in the whole axial area of its slide contacting surface (1A) with helical grooves (1B), and the height of ridges (1a) of the helical grooves (1B) is set as follows: an imaginary reference line (L) parallel to an axis of the bearing is determined in a position in which the sum of the areas of cross sections, which are obtained by cutting the helical grooves (1B) in the axial direction, of all the ridges (1a) and that of the cross-sectional areas of all the valleys (1b) become equal. A height measured from this reference line (L) to an apex (1a') of a ridge (1a) is set to 2-8 μm. Owing to the hollow spaces comprising the valleys (1b), a feed rate of a lubricating oil can be increased, whereby the reduction of the frictional resistance and hammering sound can be attained at once.

FIG. 1
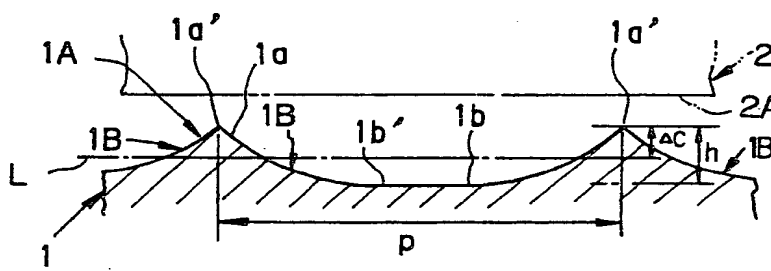
EP 0 709 585 A1

Description

Technical Field

The invention relates to a sliding bearing, and more particularly, to a sliding bearing in which annular peaks are formed on a surface which is disposed in sliding contact with a rotating shaft.

Background

Customarily, a slight clearance is produced between the surfaces of a sliding bearing and a rotating shaft which are disposed in sliding contact with each other when the rotating shaft is rotatably journalled by the sliding bearing. In such a conventional sliding bearing, when a smaller internal diameter of the surface of the sliding bearing which is disposed for sliding contact is chosen in an attempt to minimize the magnitude of the clearance, there results a disadvantage that a frictional resistance between the surfaces of the sliding bearing and the rotating shaft which are disposed in sliding contact with each other increases. Conversely, when a larger inner diameter is chosen for the sliding surface of the sliding bearing to increase the clearance in order to minimize the frictional resistance, there results another disadvantage that the occurrence of striking sound between the surfaces increases. Thus, it has been difficult in a conventional sliding bearing to achieve a reduction in the frictional resistance between the sliding surfaces and a reduction in the striking sound generated simultaneously.

Disclosure of the Invention

In view of the foregoing, the invention provides a sliding bearing including a plurality of axially spaced, annular continuous or discontinuous peaks which extend circumferentially of a surface of the sliding bearing which is disposed for sliding contact with a rotating shaft in which as viewed in the axial section, the various portions are defined on the basis of an imaginary reference line intersecting with individual peak regions and extending parallel to the axis and which is determined such that a total cross-sectional area of peak regions located above the reference line is equal to a total cross-sectional area of valley-shaped recess regions located below the reference line, the top of the peak having a height ΔC above the imaginary reference line and a height as measured from the bottom of the valley-shaped recess to the top of the peak being denoted by $\underline{h}$, the parameter ΔC being taken on an ordinate and the parameter $\underline{h}$ being taken on the abscissa in a graphical representation, the parameters ΔC and $\underline{h}$ being located within a range defined by four rectilinear lines given by the following mathematical equations:

$$h = \Delta C \qquad (1)$$

$$h = 5/1.9 \, \Delta C \qquad (2)$$

$$h = 8 \qquad (3)$$

$$\Delta C = 1 \qquad (4)$$

where $\underline{h}$ and ΔC are measured in unit of μm.

With the sliding bearing thus constructed, a lubricant oil is stored in the space of an annular groove formed between a pair of axially adjacent peaks or in the valley-shaped recess, whereby the amount of lubricant oil which is maintained between the sliding surfaces can be increased. If the internal diameter of the sliding surface of the sliding bearing is chosen small so as to reduce the clearance between the sliding surface of the rotating shaft and the sliding surface of the sliding bearing, the actual clearance left between the rotating shaft and the sliding bearing is large as compared with the conventional sliding bearing, whereby the frictional resistance experienced between the sliding surfaces can be minimized.

As to the occurrence of striking sound, the peaks on the sliding surface of the bearing and the clearance are effective in reducing the occurrence of striking sound at the same time the frictional resistance is reduced. In this manner, a reduction in the sliding resistance and a reduction in the occurrence of striking sound are simultaneously achieved.

Brief Description of the Drawings

Fig. 1 is an axial cross section of an essential part of a sliding bearing 1 according to one embodiment of the invention in an exaggerated form;

Fig. 2 graphically shows a multitude of rectilinear lines, which illustrate differences in the size of essential parts between a sliding bearing according to the invention and a conventional sliding bearing;

Fig. 3 is a graphical representation of a result of measurement of striking sound in sliding bearings of several embodiments in contrast to that of a conventional sliding bearing;

Fig. 4 graphically illustrates a result of measurement of sliding resistance of the sliding bearing according to the embodiment of the invention in contrast to that of a conventional sliding bearing;

Fig. 5 graphically illustrates a result of measurement of an oil quantity stored between the sliding surfaces in the sliding bearings of the invention in contrast to a conventional sliding bearing;

Fig. 6 is a chart indicating results of measurement of a back surface temperature of the bearing according to the invention as contrasted to conventional sliding bearing;

Fig. 7 is an axial cross section of part of a second embodiment of the invention; and

Fig. 8 is an axial across section of part of a conventional sliding bearing.

Best Mode to Carry Out the Invention

Referring to the drawings, the invention will be described below with reference to several embodiments thereof shown. Fig. 1 shows an axial section of a sliding bearing 1 according to the invention which assumes a cylindrical configuration, a sliding surface 1A being shown.

In the sliding bearing 1 according to the present embodiment, the sliding surface 1A is formed, over its entire axial region where it is disposed in sliding contact with a sliding surface 2A of a rotating shaft 2, with a helical groove 1B which is continuous circumferentially, thereby forming a peak 1a between a pair of axially adjacent grooves 1B.

When the rotating shaft 2 has an outer diameter D1 of 50 mm, for example, adjacent peaks 1a, which are formed by the grooves 1B, have a pitch p, which is chosen to be equal to 0.2 mm (200 μm). A height $\underline{h}$, as measured from the bottom 1b' of each valley 1b to the top 1a' of the peak 1a, is chosen to be equal to 8 μm at maximum.

In particular, in the present embodiment, the helical groove 1B is formed by a boring operation, and the height of the top 1a' of each peak 1a is determined in the following manner: Specifically, over the entire axial region of the sliding surface 1A in which the helical groove 1B is formed, an imaginary reference line L is determined which intersects the individual peaks 1a and which extends parallel to the axis such that a total cross-sectional area of the individual peaks 1a located above the reference line L is equal to a total cross-sectional area of the space comprising the individual valleys 1b. A height ΔC, as measured from the imaginary reference line L to the top 1a' of each peak 1a, is chosen to be in a range from 1 to 8 μm. It will be appreciated from the ratio of the described pitch p of 200 μm and the described height $\underline{h}$ which is equal to or less than 8 μm, that the actual cross-sectional configuration of the sliding bearing 1 will be far greater in the lateral or axial direction as compared with the illustration of the cross section shown in Fig. 1.

From results of experiments conducted by the applicant, which will be described later, it is found that there is obtained a preferred bearing performance from a sliding bearing 1 which is located in a range delineated by four rectilinear lines shown in graphical representation in Fig. 2 and expressed by the following mathematic equations, which define the relationship between the height $\underline{h}$, measured from the bottom 1b' of the valley 1b to the top 1a' of the peak 1a and the height ΔC, as measured from the reference line to the top of the peak:

$$h = \Delta C \qquad (1)$$

$$h = 5/1.9 \; \Delta C \qquad (2)$$

$$h = 8 \qquad (3)$$

$$\Delta C = 1 \qquad (4)$$

where $\underline{h}$ and ΔC are measured in unit of μm.

From the same results of experiments, it is found that a sliding bearing 1 which exhibits an excellent bearing performance when it is located in a range defined by four rectilinear lines, expressed by the following equations:

$$h = \Delta C \qquad (1)$$

$$h = 2 \; \Delta C \qquad (5)$$

$$h = 8 \qquad (3)$$

$$\Delta C = 1.5 \qquad (6)$$

From the same results of experiments, it is also found that the most excellent bearing performance is achieved by a sliding bearing 1 which is located in a range delineated by three rectilinear lines, expressed by the following equations:

$$h = \Delta C \qquad (1)$$

$$h = 5 \qquad (7)$$

$$\Delta C = 3 \qquad (8)$$

A sliding bearing having a groove formed in its sliding surface is disclosed in Japanese Patent Publication No. 11,530/1988, for example. When the concepts of the height $\underline{h}$, the reference line L and the height ΔC according to the present embodiment are applied to the sliding bearing disclosed in this Patent Publication, the relationship between the heights $\underline{h}$ and ΔC are represented by rectilinear lines 10 and 11.

Specifically, in the sliding bearing disclosed in Japanese Patent Publication No. 11,530/1988 (Fig. 4 thereof), the pitch $\underline{a}$ between adjacent V-shaped grooves and the diameter $\underline{d}$ of the sliding bearing are related as follows:

$$a = 200 + 0.5 \, d + 0.006 \, d^2$$

$$h/b \leq (1500 - d)/1500$$

$$(a - b)/a = 100 - 6 \, Vu^{0.6} \; (\%)$$

the denotations used being shown in Fig. 8.

Assuming that Vu = 20 m/s, for a combination of d = 50 mm, a = 240 μm, b ≤ 86 μm, and h ≤ 24 μm, a value corresponding to ΔC as termed in the present embodiment is equal to 15 μm.

If we assume that a = 240 μm, b ≤ 86 μm and h ≤ 5 μm, a value corresponding to ΔC is equal to 0.9 μm. Thus, the sliding bearing shown in Fig. 4 of Patent Publication No. 11,530/1988 is located, as considered in Fig. 2, in a range in which ΔC assumes a value which is equal to or less than the rectilinear line 10.

In the cited Patent Publication No. 11,530/1988, a groove which is trapezoidal in cross section is shown in Fig. 6 thereof. As indicated by phantom lines in Fig. 8, when the groove is perfectly rectangular in configuration, a value corresponding to ΔC will be 1.79 µm. This is illustrated in Fig. 2 by the rectilinear line 11. Accordingly, the sliding bearing having a groove as indicated by phantom lines in Fig. 8 is located in a range below the rectilinear line 11, which indicates the range of values for ΔC.

Figs. 3 to 6 indicate results of experiments conducted by mounting the sliding bearing 1 of the present embodiment and a sliding bearing disclosed in the cited Patent Publication on a rotating shaft having an identical outer diameter with an equal clearance for rotation.

The experiments have been conducted by choosing values of h = 5 µm and p = 0.2 mm for the sliding bearing 1 of the present embodiment. The clearance between the sliding surface 2A of the rotating shaft 2 and the sliding bearing 1 refers to the dimension measured across the top 1a' of the peak 1a and the sliding surface 2A of the rotating shaft 2.

Initially referring to Fig. 3 and considering the occurrence of striking sound which is developed by abutment between the rotating shaft and the sliding bearing, it is noted that in the sliding bearing of the invention in which ΔC is chosen to be equal to 0 or where no groove is formed in the sliding surface and in the conventional sliding bearing disclosed in the Patent Publication, the striking sound was measured at an acoustic level of 60 dB. By contrast, when ΔC is chosen to be equal to 2.5 µm and 3.5 µm in the present embodiment, the acoustic level is reduced by 2 to 3 dB over the prior art.

Considering the sliding resistance, it will be seen from Fig. 4 that the frictional loss torque of the rotating shaft is reduced for ΔC = 3.5 µm than for the prior art or a choice of ΔC = 0 at every number of revolutions.

Considering the quantity of lubricant oil which flows between the sliding surfaces of the sliding bearing and the rotating shaft at each number of revolutions, it will be seen from Fig. 5 that when ΔC is equal to 2.5 µm and 3.5 µm according to the present embodiment, the oil quantity is increased over the conventional bearing disclosed in the cited Patent Publication and the choice of ΔC = 0 (no groove formed in the sliding surface).

Considering the relationship between the temperature of the back surface of the sliding bearing and the oil feed temperature of the lubricant oil, it will be noted from Fig. 6 that the sliding bearing according to the present embodiment in which ΔC is equal to 3.5 µm, shown by black dots, exhibits a lower oil temperature than the sliding bearing disclosed in the cited Patent Publication which is shown in white circle.

Accordingly, experimental data shown in Figs. 5 and 6 indicate that with the sliding bearing 1 of the present embodiment, the provision of the helical groove 1B constructed in the manner mentioned above allows the quantity of lubricant oil, passing over the sliding surfaces 1A and 1B, to be increased. The frictional resistance presented by the sliding surface 1A can be reduced for the

reason mentioned before, as indicated in Fig. 4. In addition, the occurrence of striking sound between the sliding surfaces 1A and 2A of the sliding bearing of the rotating shaft 2 can be reduced, as indicated in Fig. 3.

Second Embodiment

Fig. 7 shows a second embodiment of the invention. In the first embodiment mentioned above, the valley 1b has been in the form of a gentle arc in cross section. By contrast, in the second embodiment, the valley 1b is trapezoidal in section. Accordingly, the profile of the peak 1a is in the form of a wedge having an acute angle in section. In other respects, the arrangement is similar to the first embodiment. Accordingly, similar experimental data are obtained as described in connection with the first embodiment, and therefore, a similar functioning and an effect are achieved as in the first embodiment.

In the both embodiments described above, the peak 1a is helically continuous as a result of the helical groove 1B which continues in the circumferential direction of the sliding surface 1A. However, instead of providing a helical groove, there may be a plurality of annular grooves, which are continuous in the circumferential direction, may be formed in the sliding surface at a given axial spacing, thereby providing annular peaks which are discontinuous in the circumferential direction.

Claims

1. A sliding bearing including a plurality of axially spaced, annular continuous or discontinuous peaks which extend circumferentially of a surface of the sliding bearing which is disposed for sliding contact with a rotating shaft in which as viewed in the axial section, the various portions are defined on the basis of an imaginary reference line intersecting with individual peak regions and extending parallel to the axis and which is determined such that a total cross-sectional area of peak regions located above the reference line is equal to a total cross-sectional area of valley-shaped recess regions located below the reference line, the top of the peak having a height ΔC above the imaginary reference line and a height as measured from the bottom of the valley-shaped recess to the top of the peak denoted by $\underline{h}$, the parameter ΔC being taken on an ordinate and the parameter $\underline{h}$ being taken on the abscissa in a graphical representation, the parameters ΔC and $\underline{h}$ being located within a range defined by four rectilinear lines given by the following mathematical equations:

$$h = \Delta C \qquad (1)$$

$$h = 5/1.9 \, \Delta C \qquad (2)$$

$$h = 8 \qquad (3)$$

$$\Delta C = 1 \qquad (4)$$

in which $\underline{h}$ and ΔC are measured in unit of μm.

2. A sliding bearing including a plurality of axially spaced, annular continuous or discontinuous peaks which extend circumferentially of a surface of the sliding bearing which is disposed for sliding contact with a rotating shaft in which as viewed in the axial section, the various portions are defined on the basis of an imaginary reference line intersecting with individual peak regions and extending parallel to the axis and which is determined such that a total cross-sectional area of peak regions located above the reference line is equal to a total cross-sectional area of valley-shaped recess regions located below the reference line, the top of the peak having a height ΔC above the imaginary reference line and a height as measured from the bottom of the valley-shaped recess to the top of the peak, denoted by $\underline{h}$, the parameter ΔC being taken on an ordinate and the parameter $\underline{h}$ being taken on the abscissa in a graphical representation, the parameters ΔC and $\underline{h}$ being located within a range defined by four rectilinear lines given by the following mathematical equations:

$$h = \Delta C \qquad (1)$$

$$h = 2\,\Delta C \qquad (2)$$

$$h = 8 \qquad (3)$$

$$\Delta C = 1.5 \qquad (4)$$

in which h and ΔC are measured in unit of μm.

3. A sliding bearing including a plurality of axially spaced, annular continuous or discontinuous peaks which extend circumferentially of a surface of the sliding bearing which is disposed for sliding contact with a rotating shaft in which as viewed in the axial section, the various portions are defined on the basis of an imaginary reference line intersecting with individual peak regions and extending parallel to the axis and which is determined such that a total cross-sectional area of peak regions located above the reference line is equal to a total cross-sectional area of valley-shaped recess regions located below the reference line, the top of the peak having a height ΔC above the imaginary reference line and a height as measured from the bottom of the valley-shaped recess to the top of the peak, denoted by $\underline{h}$, the parameter ΔC being taken on an ordinate and the parameter $\underline{h}$ being taken on the abscissa in a graphical representation, the parameters ΔC and $\underline{h}$ being located within a range defined by four rectilinear lines given by the following mathematical equations:

$$h = \Delta C \qquad (1)$$

$$h = 5 \qquad (2)$$

$$\Delta C = 3 \qquad (3)$$

in which h and ΔC are measured in unit of μm.

4. A sliding bearing according to one of Claims 1 to 3 in which a helical groove is formed in the sliding surface to define an annular continuous peak which extends circumferentially between axially adjacent grooves.

5. A sliding bearing according to one of Claims 1 to 3 in which a plurality of annular grooves are formed in the sliding surface to define a plurality of annular peaks which extend circumferentially between axially adjacent annular grooves, adjacent peaks being discontinuous from each other.

6. A sliding bearing according to one of Claims 1 to 5 in which the valley-shaped recess is in the form of a gentle arc in cross section.

7. A sliding bearing according to one of Claims 1 to 5 in which the valley-shaped recess is trapezoidal in cross section.

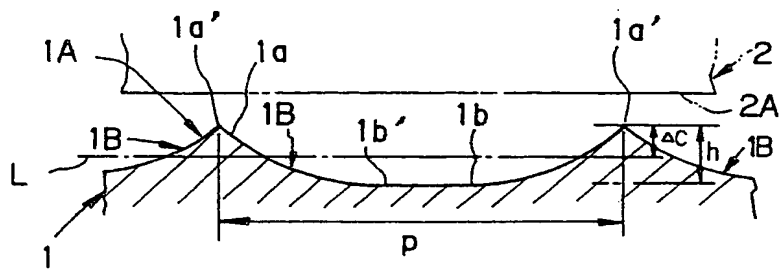8. A sliding bearing according to one of Claims 1 to 7 in which the adjacent peaks has a pitch of about 200 μm.

FIG. 1

FIG. 2

FIG.3

prior art ($\triangle$C=0.5μm)

embodiment ($\triangle$C=0μm)

dB 60

embodiment($\triangle$C=2.5μm)

embodiment($\triangle$C=3.5μm)

55

2.5   3.5

$\triangle$C (μm)
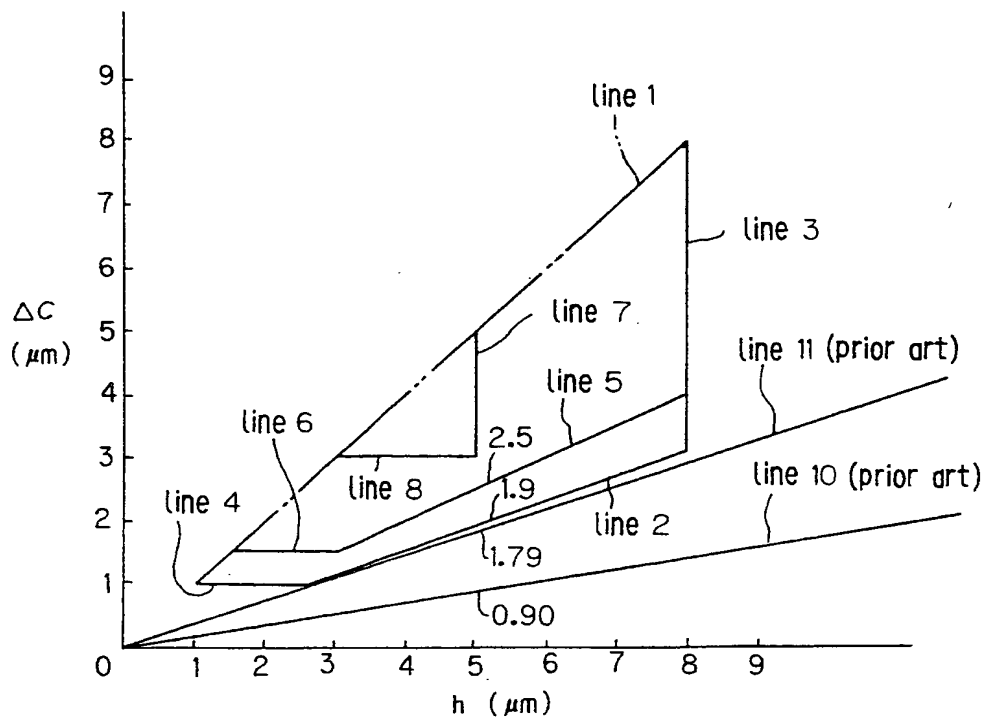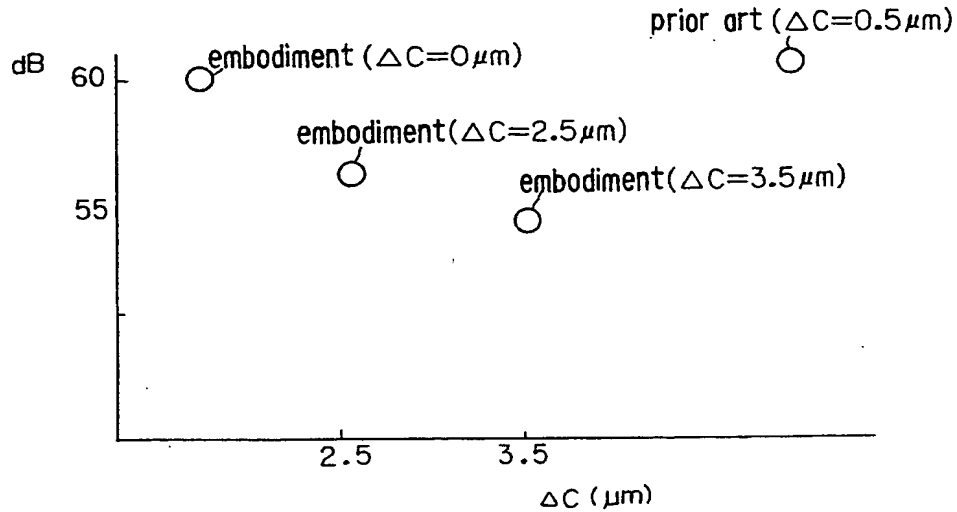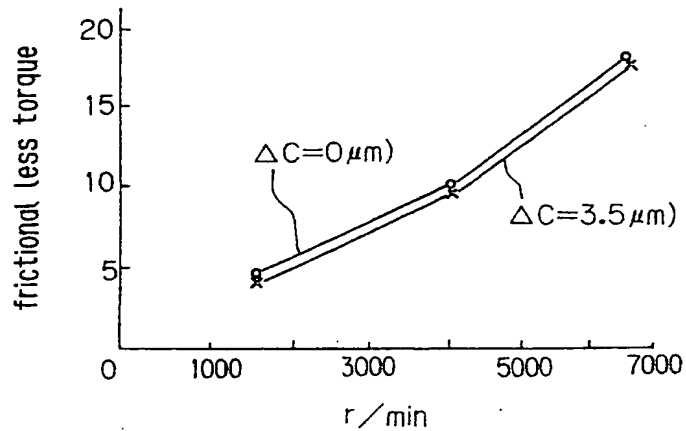
condition of experiment :

 sound pressure level from series four cylinder engine,
when operated at 1500 rpm and half-load, is measured
with a microphone.

FIG.4

frictional less torque

20

15

$\triangle$C=0μm)

10

$\triangle$C=3.5μm)

5

0 1000 3000 5000 7000

r／min

condition of experiment :

 series four cylinder engine oil temperature of 80±1 ℃
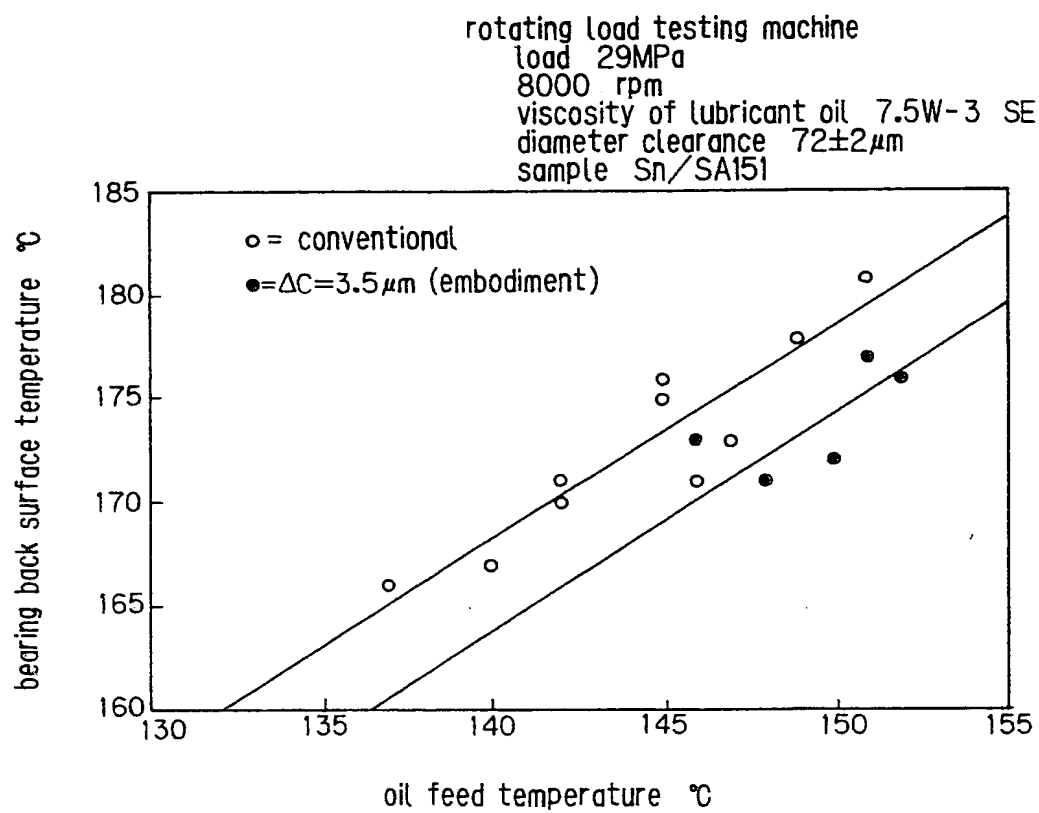oil variety 7.5w-30 oil clearance of 45 μm

7

F I G. 5

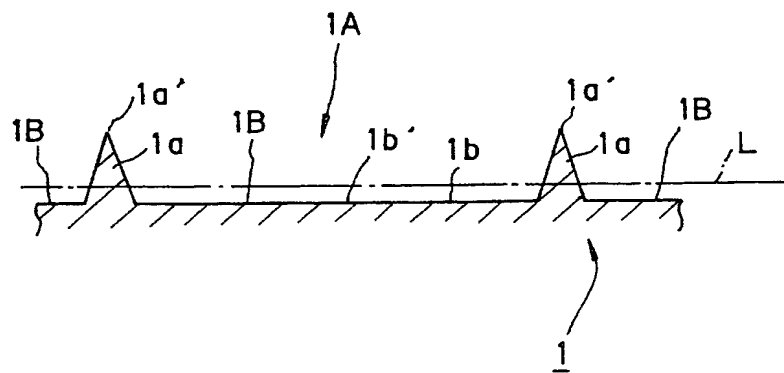number of revolutions : 4000r/min

load : rod side 3 ton   cap side 5 ton

oil type : 7.5W-30

oil feed temperature : 120±1℃

oil clearance : 56~57 μm

ΔC=0μm (conventional)

ΔC=3.5μm

ΔC=2.5μm

ΔC=0.5μm(conventional)

oil feed pressure MPa

bearing oil quantity L/min

FIG.6

rotating load testing machine
load 29MPa
8000 rpm
viscosity of lubricant oil 7.5W-3 SE
diameter clearance 72±2μm
sample Sn/SAl5l
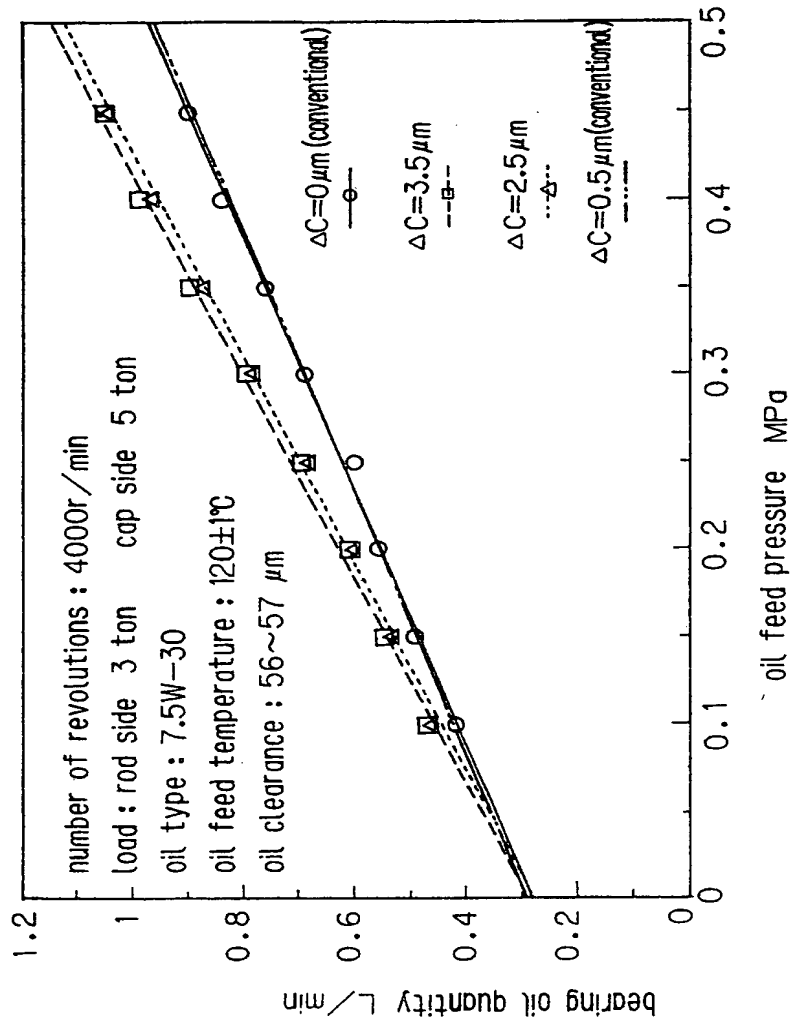
FIG.7

FIG.8
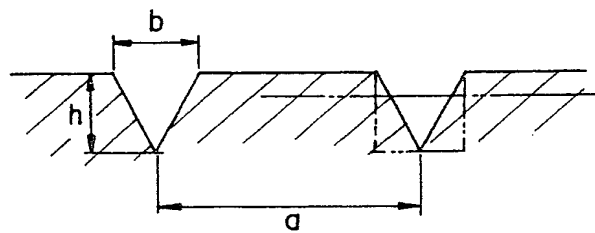
INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP95/00467

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^6 F16C33/10, 33/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl^6 F16C33/10, 33/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1926 - 1995
Kokai Jitsuyo Shinan Koho	1971 - 1995

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 4-39461, Y (Toyota Motor Corp., Taiho Kogyo Co., Ltd.), September 16, 1992 (16. 09. 92), Line 16, column 2, page 1 to line 26, column 3, page 2 (Family: none)	1 - 8
Y	JP, 63-30619, U (Toyota Motor Corp., Taiho Kogyo Co., Ltd.), February 29, 1988 (29. 02. 88), Claim (Family: none)	1 - 8

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
June 12, 1995 (12. 06. 95)	July 4, 1995 (04. 07. 95)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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